are more prevalent in the winter than in the summer would indicate that the temperature is vitally important in their existence. In this higher level we find southwest predominating, although the range is from south to west. This is especially true in the summer, as in the winter the winds are more variable. Velocities are higher and, although the increase is not great in summer, there is a tendency toward stronger winds, particularly in the cooler months of the year.

TABLE 4.—*4,000 meters above sea level*
[Velocities in meters per second; fractions omitted]

	Summer				Winter			
	A. M.		P. M.		A. M.		P. M.	
	Number	Average velocity	Number	Average velocity	Number	Average velocity	Number	Average velocity
N	3	7	9	3	3	7	17	9
NNE	3	10	6	5	8	3	4	11
NE	1	3	4	8	11	7	5	8
ENE	2	6	3	3	2	8	12	9
E	3	6	1	11	0	0	5	8
ESE	2	2	6	6	2	3	3	7
SE	3	4	4	4	0	0	4	4
SSE	5	6	9	5	3	7	2	6
S	5	9	11	10	0	0	6	6
SSW	14	12	16	11	0	0	8	9
SW	14	10	29	9	5	12	10	10
WSW	13	10	26	10	4	15	16	12
W	6	8	14	8	5	19	4	14
WNW	5	7	12	6	5	8	16	10
NW	4	5	4	6	11	14	12	14
NNW	2	6	10	3	8	12	10	15

The conditions found at 2,000 meters extend upward through the other two levels, with an ever improving advantage to the eastbound flier. During the summer the sector south to west prevails, while during winter, the directions are from west to north.

Briefly, then, the fact that Phoenix has a greater number of easterly surface winds does not indicate that the upper currents differ from those over the country in general. On the contrary, we find that the movement is from the western portion of the compass. However, the upper winds cover a wider range of directions than are found to exist in many sections of the United States. This may be due to the location of Phoenix at a point considerably south of the usual paths of the cyclones and anticyclones.

Upper-air investigation has revealed several interesting features of the atmosphere in this region. Surface winds are usually light, and, particularly on hot afternoons, this "stagnation" often extends to considerable altitude. Balloons have been followed to 4,000 meters and 5,000 meters with elevation angles remaining above 60°. Graphs of such runs show every point of the compass.

Estimating ceiling or cloud height.—Most observers learn to associate cloud formations with altitudes, so when one is known, the other can be more readily estimated. Such individuals face a problem in this locality until the acquisition of sufficient data warrants definite estimates. Of the 1,150 balloon runs made to date, cloud altitudes have been ascertained in exactly 100 instances, but these, with 3 exceptions have been confined to 3 cloud types. Strato-cumulus lead in frequency, ranging in altitude above the surface from 1,100 to 4,200 meters, with an average of 2,250 meters. The two remaining types share equally as to frequency but show considerable variation in altitude. Alto-cumulus range from 2,400 to 6,400 meters with an average of 3,700 meters, as compared with an average of 5,400 meters for alto-stratus, which showed a range from 4,000 to 8,000 meters. Comparison with the cloud altitude charts in common use indicates that clouds in southern Arizona average somewhat higher than in other portions of the country.

Everything considered, flying conditions are very favorable in this section. An average of only 41 cloudy days, 39 of which with a measureable amount of precipitation, per year; no ice-forming weather; no snow; very little fog; and very few high winds, 43 miles per hour being a 35-year maximum, are some of the outstanding reasons why this has been designated "the fair weather route." Add to this the favorable upper winds as outlined above, and this locality's desirability as a flying center can be readily appreciated.

DIMINISHING WINTER RADIATION FROM SUN AND SKY AT MADISON, WIS.

By ERIC R. MILLER
[Weather Bureau, Madison, Wis.]

A continuing decrease of the insolation registered at Madison with the Callendar bolometric sunshine recorder was pointed out by Mr. A. F. Piippo (*1*) and the question whether it was due to city smoke or to deterioration of the apparatus was considered by Dr. H. H. Kimball in a note to the same paper. The present paper adds further data and applies statistical methods to their interpretation.

Smokiness in Madison is mostly due to heating, since the city is administrative, educational, and residential rather than industrial. The few industrial plants are located 3 or 4 miles east of the Weather Bureau station, and the prevailing winds are northwest in winter, southwest in summer. The university heating plant with chimney 250 feet high is 1,000 feet south-southwest of the station. Its annual consumption of coal (in tons of 2,000 pounds) in years ending June 30, was:

	Tons		Tons
1912–13	19, 576	1922–23	20, 649
1913–14	20, 489	1923–24	21, 693
1914–15	19, 640	1924–25	21, 076
1915–16	20, 039	1925–26	24, 773
1916–17	22, 986	1926–27	25, 963
1917–18	18, 670	1927–28	28, 463
1918–19	22, 162	1928–29	30, 554
1919–20	20, 429	1929–30	30, 153
1920–21	19, 183	1930–31	29, 446
1921–22	19, 997		

The smoke from this chimney always drifts off in a compact stream before diffusing. The proportion of black smoke has been greatly decreased in recent years by improvements in the furnaces to bring about complete combustion. It is not possible to present similar statistics of the use of coal for domestic heating. A notion of the change is afforded by the census reports of the population of the tenth ward, which includes the western part of the city beyond the university:

1910	1,092
1920	3,664
1930	9,590

When the sunshine record was begun, anthracite was largely used for house heating. Since then there has been a shift to bituminous and to oil.

Winter being the season of smoke emission, the data from the Callendar sunshine recorder have been separated as follows:

Calories per square centimeter of horizontal surface

December–March	Calories	June–September	Calories	Year	Calories
1911–12	29,473	1911	58,025	1911	125,267
1912–13	26,267	1912	55,895	1912	122,855
1913–14	24,189	1913	57,974	1913	122,818
1914–15	26,253	1914	57,808	1914	123,777
1915–16	25,200	1915	50,191	1915	114,087
1916–17	28,753	1916	58,547	1916	125,072
1917–18	28,763	1917	55,167	1917	122,092
1918–19	23,240	1918	55,825	1918	120,593
1919–20	26,490	1919	56,060	1919	116,857
1920–21	21,009	1920	56,949	1920	121,618
1921–22	25,004	1921	57,239	1921	116,286
1922–23	25,437	1922	55,847	1922	118,434
1923–24	22,948	1923	52,638	1923	118,197
1924–25	23,814	1924	51,652	1924	112,606
1925–26	23,002	1925	56,376	1925	119,234
1926–27	23,026	1926	52,542	1926	115,486
1927–28	25,629	1927	56,583	1927	112,552
1928–29	23,319	1928	54,688	1928	119,015
1929–30	23,829	1929	56,009	1929	117,161
1930–31	21,525	1930	57,757	1930	120,136
Mean	24,858		55,689		119,207

The secular trend of each of these series has been found by fitting regression lines, using the method described by Persons (**2**), pages 158–160. These equations, in which the coefficient is the rate of change in calories per year, are:

		Per cent per annum	Per cent in 20 years
December–March	$y=-244.3x$	−0.982	−19.64
June–September	$y=-77.4x$	−0.139	−2.78
Year	$y=-391.4x$	−.329	−6.58

Of the annual decrease, 62 per cent occurs in the 4 months December–March.

The method of testing the significance of regression coefficients due to "Student" (**3**), pages 115–124, has been applied to these data with the following results:

	Std. error	t	P.
December–March	73.5	3.32	<0.01
June–September	90.3	.86	.40

where P. is the probability that a random sample will have a value of t falling outside the value found here. The regression coefficient for the summer months is evidently not significant, while that for the winter is highly significant.

Such a change could be brought about by an increase of cloudiness. Eye observations of the cloudiness during daylight hours have been made at Madison (bihourly since September, 1918), and the secular trend of cloudiness is shown by the following:

		Per cent per annum	Per cent in 20 years
December–March	$y=-0.0098x$	−0.151	−3.02
June–September	$y=-0.2.64x$	−0.489	−9.78

The observed trend of cloudiness is just the opposite of what is required to explain the decrease in the observed radiation.

However, it must be remembered that smoke, haze, and fog are excluded in making the estimate of cloudiness, hence an increase in smokiness should produce a decrease in the recorded cloudiness to the extent that clouds are obscured by smoke.

The hours of bright sunshine, registered by the thermometric sunshine recorder in the same 20 years, show the secular trend indicated by the following equations:

		Per cent per annum	Per cent in 20 years
December–March	$y=-5.05x$	−0.906	−18.12
June–September	$y=-.0069x$	−.00428	−.09

The percentage change of these data for December–March, agrees remarkably closely with the change in calories. The coefficient of correlation between calories and hours of sunshine for December–March is 0.75, which is less than would be expected from the similarity of secular trends.

Deterioration of the Callendar apparatus is believed by Doctor Kimball (1) page 504, to be indicated by the comparisons that have been made between the Callendar apparatus and the Marvin pyrheliometer. Since the Callendar apparatus registers the vertical component of sun and sky radiation, while the Marvin instrument is exposed normally to the sun's rays, the comparisons are made by shading the Callendar receiver, and reducing the drop in ordinate, trigonometrically. In series of observations made in 1913–1915 and in 1917 the shading of the Callendar instrument was simultaneous with the observations with the Marvin pyrheliometer, with the result that the trace of the recorder had to be interpolated. In 1927, the relatively smooth base line representing sky radiation only, was obtained by shading the Callendar apparatus before and after the pyrheliometer readings. This change of technique introduces some uncertainty into the comparisons. The results obtained vary with the altitude of the sun, so that there is either a variation of sensitiveness of one or other of the two instruments, or the trigonometric relations are not as assumed.

Results of comparisons to the end of March, 1927, were given by Doctor Kimball in the paper referred to. Some 37 additional comparisons were made in 1927. The following tables include all of the comparisons:

Number of comparative observations in each group

1913–1915	15	16	14	3	2	2
1917	10	7	5	4		
1927	10	31	24	14	5	1

Average solar altitude of each group

1913–1915	58.3	43.0	29.8	20.1	15.9	14.3
1917	60.6	43.6	30.2	21.7		
1927	55.7	41.5	30.5	22.1	16.5	12.6

Average factor (f.) to reduce Callendar to Marvin

1913-1915	0.0346	0.0342	0.0354	0.0380	0.0423	0.0502
1917	.0353	.0354	.0377	.0371	-------	-------
1927	.0354	.0356	.0358	.0381	.0418	.0489

Standard deviation of the observations of f.

1913-1915	0.0010	0.0018	0.0018	0.0024	0.0017	0.0015
1917	.0011	.0010	.0019	.0038	-------	-------
1927	.0020	.0013	.0023	.0031	.0051	-------

Standard error of the mean f. in each group

1913-1915	0.0003	0.0005	0.0005	0.0017	0.0017	0.0015
1917	.0004	.0004	.0010	.0022	-------	-------
1927	.0007	.0002	.0005	.0008	.0026	-------

Increase of f.

1913-1915 to 1917	*0.0007*	0.0012	0.0023	0.0009	-------	-------
1913-1915 to 1927	.0008	.0014	*.0004*	*.0001*	0.0005	-------
1917 to 1927	.0001	*.0002*	.0019	.0010	-------	-------

The best value of the change of f. in each column, i. e. the one obtained from the means having the smallest standard error at both beginning and end of the interval, is indicated by italicizing. It will be observed that these changes are mostly smaller than the standard errors of the means on which they are based, whereas the differences should be three times as large as the standard errors to indicate progressive change, with certainty.

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Statistical methods for research workers, 3d ed. Edinburgh, 1930.

DISCUSSION

It is a source of gratification that further comparisons between the Marvin and the Callendar pyrheliometer in use at Madison cast doubt upon a possible deterioration in the Callendar instrument, which earlier comparisons seemed to indicate. On account of the small number of these comparisons in the different periods compared, this point can not be considered definitely settled, however. It is therefore hoped that additional comparisons may be obtained from time to time.

I may add that similar comparisons that are obtained during nearly every month at Lincoln, Nebr., have not shown an appreciable change in the reduction factor for the Callendar pyrheliometer in use at that station, except on one occasion, when the bridge wire was injured and had to to be replaced.

Mr. Miller's paper shows quite conclusively that the progressive diminution in the annual totals of radiation received at Madison is attributable to the increased smokiness of that part of the city in which the university and the Weather Bureau are located, due to the change from anthracite to bituminous coal for heating dwellings, and an increase in the number of dwellings in the university section of the city. The same thing is true at the American University, District of Columbia, where, also, the depletion is confined to the winter months.—*H. H. Kimball.*

THE FUTURE OF AGRICULTURAL METEOROLOGY

By W. A. MATTICE

[Weather Bureau, Washington, August, 1931]

In these days of overproduction of agricultural products, with a corresponding depression of prices, the thoughts of the Nation turn to the plight of the farmer. There are many experiment stations, experimental farms, and various governmental agencies that are continually advising the farmer what crops to grow and what crops not to grow, but has the weather received full consideration in these opinions? The ever-present alchemist that transmutes base materials into the gold of the ripe wheat, corn, etc., has been scarcely accorded the measure of respect due the vast power wielded. The weather in its effect on agriculture has been scrutinized from afar, as through a long-range telescope, but very little has been accomplished in pursuing the microscopic detail necessary for complete understanding of the underlying principles involved in crop growth. The experimenter in physics, for example, does not attack his problems with the pick and shovel of the day laborer, but with intricate machinery, delicate lenses, accurate micrometers, etc. The comparison is perfectly analogous, for the present-day researches in agricultural meteorology are conducted on a grand scale, a State unit, district unit, or even a country-wide unit. The wealth of detail obtainable on such scales are meager, it is indeed, comparable to the pick and shovel of the day laborer. We might as well supply the archeologist with dynamite alone and expect him to return with the delicate murals, friezes, urns, etc., that are obtained only through infinite patience and careful brushing and screening of minute fragments.

Statistical studies of crop production as related to weather conditions have been and are still being made, with variable results. It is the present experience of investigators that, a series of correlations reaching a coefficient of 0.90, or a little better, is about as good as can be expected with available crop and weather data. However, a coefficient of 0.90 leaves much to be desired, for even with one this high there still remains 43 per cent of the spread between the actual and computed figures to be accounted for outside the data included in the equations. How can this gap be bridged; and is the inadequacy of the data the stumbling block?

The Weather Bureau includes in its meteorological statistics for first-order stations, in addition to temperature and rainfall, the hours of sunshine, direction of the wind, state of the weather, barometric pressure, vapor pressure, relative humidity, etc. Perhaps these, or at least some of them, have important relations to crops, but what material benefit are they when measured on the top of an office building sometimes four or five, or even more, miles from the nearest crops? Again, these first-order stations are widely separated—they are seldom nearer than 50 miles from each other and the various States rarely have over six or seven of them. What variations in the weather occur between them?